Qualification, Demonstration & Validation of Compliant Removers for Aircraft Sealants and Specialty Coatings ESTCP WP-0621

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UDRI
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PROJECT TEAM

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  - Mr. David Tanner (OC-ALC)
  - Mr. Jerome Jenkins (OO-ALC) **DEM/VAL at Hill AFB**
- **Navy**
  - Ms. Diane Kleinschmidt, Navy Lead (NAVAIR)
  - Mr. Brad Youngers (FRC-SE) **DEM/VAL at FRC-SE**
  - Mr. Don Harmston (NADEP North Island)
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- **Battelle**
  - Mr. Jim Tankersley, Program Coordinator
  - Mr. John Stropki, DEM/VAL Coordinator
- **UDRI**
  - Ms. Susan Saliba
  - Mr. John Dues

TECHNICAL OBJECTIVES

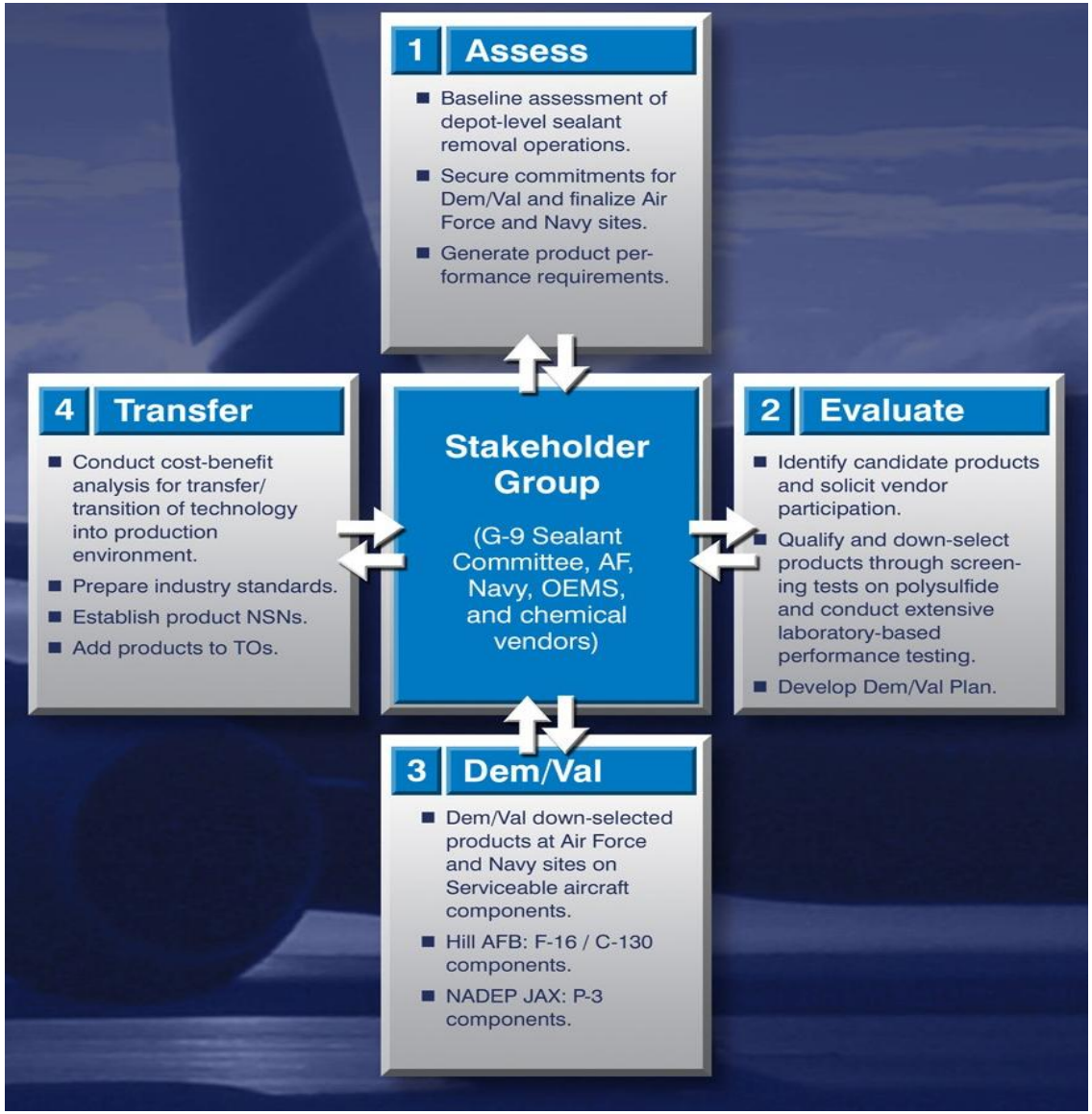
Objective:

- To demonstrate and validate performance of COTS environmentally friendly *(contains no TRI chemicals, no HAPs, or chlorinated compounds)* chemical strippers for use on MIL-SPEC sealants and specialty coatings
- Conduct a field-level Demonstration/Validation of non-mechanical processes for removing sealants and specialty coatings from metallic aircraft structures
- Reduce Environmental Burdens
- Increase Performance
- Control Costs

TECHNICAL APROACH

- Phase I (FY06, FY07)
  - Polysulfide and silicone sealants
  - Dem/Val 1 at Hill AFB
    - F-16, C-130
  - Dem/Val 2 at FRCSE
    - P-3 OML
- Phase II (FY08, FY09)
  - Polythioether and polyurethane sealants
  - Dem/Val 3 at New River MCAS
    - V-22 Osprey

TECHNICAL APROACH



"Toolbox" Approach:

Provide end users with materials/methods to approach sealant removal tasks consistently and effectively, depending upon situation.

TECHNICAL APROACH

- **Task 1. Technology Demonstration Plan**
  - Establish stakeholder team
  - Draft technology demonstration plan
- **Task 2. Technology Qualification**
  - Establish qualification test plan
  - Screening tests for strippers supplied by vendors
  - Comprehensive testing for down-selected strippers
- **Task 3. Technology Validation**
  - Demonstration on condemned and serviceable parts
- **Task 4. Technology Transfer**
  - Draft technology transfer plan
  - Assist in writing changes to Tech Orders
  - Establish NSNs for strippers
- **Task 5. Regulatory Data/Support**

TECHNICAL PROGRESS

- ESTCP approved project expansion in FY08/FY09
  - Polythioether/urethane sealants and specialty coatings
  - Define materials compatibility with composite structures and specialty coatings
- Goal is to qualify more elements for use in field-level repairs using the “toolbox” approach
- Sealant team benefits from significant input/cooperation from vendor stakeholders
- Team capitalizing on “lessons learned” from Phase I efforts to apply to expanded testing and demonstration validation on additional sealants and substrates in FY08/FY09

TECHNICAL PROGRESS

- **Conducted baseline survey/analysis completed by USAF and USN stakeholders (Sept. 06, updated Nov. 08)**
- **Requirements Definition Drafted (Sept. 06, currently updating for Phase II)**
- **Selected and Finalized Demonstration Sites (Oct. 06)**
  - OO-ALC, UT (Phase I January 2008)
  - NADEP JAX, FL (Phase I April 2008)
  - MCAS New River, NC (Phase II January 2010)
- Completed Phase I Report (November 2008)

TECHNICAL PROGRESS

- Technology Demonstration Plan (Draft March 07; Final June 07)
- Product Testing to Requirements Definition (Jan. 08)
- Demonstration Validation at OO-ALC (Feb. 08)
  - F-16 Wing Spar/Pylons
  - A-10 Wing IML
  - C-130 Sloping Longeron
- Demonstration/Validation at FRC-SE (Mar. 08)
  - P-3 OML
  - P-3 Wing tank components
  - EA-6B Canopy Structure
- Demonstration/Validation at MCAS New River (Jan. 2010)
  - V-22 Osprey Wing Components and OML

TECHNICAL PROGRESS

Phase I Laboratory Demonstration Tests (UDRI)

- **Sealant Materials**
  - PR-1422 B-2 (Polysulfide) – AMS-S-8802
  - PR-1750 B-2 (Polysulfide) – AMS 3276
  - PR-1826 B-2 (Polythioether) – AMS 3277
- **Coated Substrates**
  - MIL-C-27725 (Polyurethane)
  - MIL-PRF-23377 (Epoxy Primer)
  - BMS 10-20 (Epoxy Primer)
- **Uncoated Substrates**
  - AMS 2471 (Anodized Aluminum)
  - AMS 4911 (Titanium)
  - AS-4/3501-6 (Graphite/Epoxy)
  - IM-7/5250-4 (Graphite/Bismaleimide)

TECHNICAL PROGRESS

Laboratory Demonstration Tests (UDRI) - Testing Protocols

Parameter	Test	Test Method
Sealant Removal	Force Measuring Unit	UDRI Proprietary
Substrate Damage Potential	Visual	Fourier Transform Infrared Microscopy (FTIR)
	Discoloration (metallic)	ASTM G 1
	Pitting (metallic)	ASTM G-46
	Visual - 100X (composite)	Scanning Electron Microscopy (SEM)
	Interlaminar Shear Strength	ASTM D 2344
	Tensile Strength	ASTM E 8
Surface Residue	Pencil Hardness	MIL-C-83286A
	Tape Adhesion	FED STD 141, Method 6301
Re-Adherence	Peel Strength	AS 5127

Note: Removal methods included application of respective chemical removers w/ and w/o automated (powered) scrapers

Summary of Phase I Laboratory Results

- Solutia SkyKleen 2000 did not appreciably affect any of the coatings
- Poly-Gone 300 locally damaged the BMS 10-20 topcoat
- Neither paint remover affected the pencil hardness and tape test results after stripping
- AMS-2471 and AMS-4911 tensile and % elongation properties were not affected by either stripper
- The results of the interlaminar shear strength were not affected by either paint remover
- The SEM photos at 100X were inconclusive, therefore, select specimens being evaluated at 500X to determine if there was damage caused by either the paint remover or hand held tool
- Substrates stripped with Solutia SkyKleen 2000 had 100% cohesive failures on all substrates with all sealants, except PR 1750 B-2/AMS-2471 which was 95% cohesive
- Substrates stripped with Poly-Gone 300 did not have 100% cohesive failure on the majority of the substrates with sealants PR 1422 B-2 and PR 1750 B-2
- Both paint removers did not cause a change in lap shear test results

Phase I DEM/VAL Site Locations

Air Force Test Site

- Hill AFB (Ogden UT; February 12 – 14, 2008)
  - C-130 sloping longeron (OML)
  - F-16 and A-10 wing/wing component parts (IML)

Navy Test Sites

- FRC-SE (Jacksonville FL; March 26, 27, 2008)
  - P-3 Aircraft structures (OML)
  - Selection based on end-user application

OO-ALC
Demonstration/Validation Summary

- **F-16**
  - When coupled with Cold Jet, both removers showed potential to reduce stripping operations by 50%
  - Easier clean-up with SkyKleen 2000
- **C-130**
  - Both products worked adequately, but did not improve the current method (methylene chloride – 2 hr. dwell); however, PPE and evacuation of area is required with current method
- **A-10**
  - Center wing spar tested, but neither stripper was preferred to the current method due to dwell time requirement and methodology
- **All**
  - Viscosity is key to successful removal of sealant from vertical surfaces and seems to aid in clean-up

FRC-SE JAX
Demonstration/Validation Summary

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- **Applied Poly-Gone 300 to OML of P-3 Aircraft**
  - Used varying viscosities (Gel;Liq - 2:1, 1:1, 0:1)
  - Dwell time ~4 hrs.
  - Removal using pressurized water not as effective as anticipated
- **SkyKleen 2000 applied at later date by USN personnel**
  - Dwell time ~5-6 hrs.
  - Greater viscosity than Poly-Gone slurry
  - Removal using pressurized water not as effective as Poly-Gone 300
- **Lessons Learned**
  - When possible, apply when longer dwell time can be taken advantage of (possibly overnight)
  - Refine viscosities for greater effectiveness
  - Refine removal method, possibly with knife edge water jet nozzle, to increase effectiveness of pressurized removal

Cost Analysis - Phase I

Comparison of P-3 Aircraft Desealing Process Costs (based on 25 aircraft/yr)

	Baseline Scenario Mechanical Desealing	Alternative Scenario Chemical + Mechanical Desealing
Initial Investment Cost		
Capital Equipment	N/A	N/A
Annual Operating Cost		
Direct Labor	$192,000	$96,000
Direct Materials:	$37,500	$69,500
Aluminum tape/aircraft (unit $)	$25,000	$12,500
Sanding disks/aircraft (unit $)	$5,000	$1,000
Plastic and SS wire scrapers (unit $)	$7,500	$1,000
Desealant chemical (unit $)	$0	$55,000
Total	**$229,500**	**$165,000**
Utilities:		
Electric Steam/Rinse Water		
Total	**$2,400**	**$2,400**
Waste Management:		
Non-Hazardous Waste Disposal	Negligible	Negligible
Wastewater Treatment/Disposal	$85,200	$85,200
Wastewater: Hazardous Waste	$2,936	$2,936
Wastewater: Sludge	$4,607	$4,607
Total	**$92,743**	**$92,743**
Environmental Compliance Recurring Cost	N/A	N/A

Cost Analysis - Phase I

Comparison of F-16 Aircraft Lower Wing Desealing Process Costs (based on three aircraft wings/month)

	Baseline Scenario Mechanical + CO_2 Desealing	Alternative Scenario Chemical + CO_2 Desealing
Initial Investment Cost		
Capital Equipment	N/A	N/A
Annual Operating Cost		
Direct Labor	$21,600	$12,960
Direct Materials:	$6,750	$8,100
Aluminum tape/aircraft (unit $)	$0	$0
Rotary brushes/aircraft (unit $)	$0	$0
Plastic scrapers/aircraft (unit $)	$600	$300
Dry ice pellets/aircraft (unit $)	$6,150	$4,500
Desealant chemical/aircraft (unit $)	$0	$3,300
Total	**$28,350**	**$21,060**
Utilities:		
Rinse Water	$0	$0
Waste Management:		
Non-Hazardous Waste Disposal	Negligible	Negligible
Wastewater Treatment/Disposal	N/A	N/A
Hazardous Waste/Disposal	$375	$146
Sludge/Disposal	$0	$300
Total	**$375**	**$581**
Environmental Compliance Recurring Cost	N/A	N/A

Cost Analysis - Phase I

Comparison of C-130 Sloping Longeron Desealing Process Costs (based on 4 aircraft/month)

	Baseline Scenario Chemical + Mechanical Desealing	Alternative Scenario Chemical + Mechanical Desealing
Initial Investment Cost		
Capital Equipment	N/A	N/A
Annual Operating Cost		
Direct Labor	$3,840	$3,840
Direct Materials:	$1,090	$2,650
Tarping and rags/aircraft (unit $)	$400	$1,000
Plastic scrapers/aircraft (unit $)	$400	$400
Desealant chemical/aircraft (unit $)	$290	$1,250
Total	**$4,930**	**$7,450**
Utilities:	Negligible	Negligible
Rinse Water		
Waste Management:		
Non-Hazardous Waste Disposal	$250	$250
Solid Waste Treatment/Disposal	N/A	N/A
Hazardous Liquid Waste/Disposal	$275	$146
Sludge/Disposal	N/A	N/A
Total	**$475**	**$396**
Environmental Compliance Recurring Cost	N/A	N/A

Cost Analysis - Phase I Summary

- **P-3 Outer Moldline**
  - **Potential to save $64,500 annually (based on throughput of 25 A/C)**
  - **Annual savings likely less due to depot scheduling requirements**
- **F-16 Component Parts (lower wing)**
  - **Potential annual savings of $7,046 (based on three aircraft/wings per month)**
  - **Savings could be significantly greater if throughput is doubled, as data indicate**
- **C-130 Sloping Longeron**
  - **Increase in annual cost (~$7K) can be recovered through manpower efficiency and possible increased throughput**

TECHNICAL PROGRESS

Down-selected candidate sealant removers for Phase II

- Test Panels
  - 4 in. x 6 in. x 0.032 in. unclad 2024-T3 aluminum alloy
- Sealants
  - Polythioether
    - SAE AMS 3277D, PR-1826, Cl B
  - Polyurethane
    - SAE AMS 3278A, EFC-100/EF-5992
- Removers Qualified
  - Elixair Sky Restore
  - Solutia SkyKleen 2000

TECHNICAL PROGRESS

Phase II Laboratory Demonstration Tests (UDRI)

- PR 1826 B-2 polythioether sealant (qualified to AMS 3277)

Coating or Substrate	Type
MIL-PRF-27725	Polyurethane
AS4/3501	Epoxy Graphite
IM-7/5250-4	BMI

TECHNICAL PROGRESS

Preliminary Phase II Laboratory Results

- Elixair® SkyRestore and Solutia SkyKleen sealant removers did not chemically degrade the MIL-PRF-27725 coating nor either of the two composite substrates
- Neither remover affected the pencil hardness and tape test results after stripping
- Both removers had 100% cohesive failures on AS4/3501 and IM-7/5250-4

Additional laboratory results, and laboratory results on polyurethane sealants, pending

MCAS New River Demonstration/Validation

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Summary of Individual Test Areas Along Upper Surfaces of V-22 Wing Section

Test Area Identification	Approximate Length, in.	Condition	Approximate Dwell Time, hr.
Area 1 Skyrestore	9 9	Scored Unscored	2 2
Area 2 Skyrestore	9 9	Scored Unscored	4 4
Area 3 Skyrestore	12	Unscored	6
Area 1 Skykleen	9 9	Scored Unscored	6 6
Area 2 Skykleen	9 9	Scored Unscored	22 22

MCAS New River Demonstration/Validation

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Sealant Removal Times for Sealants Processed with Skykleen Remover

Test Area Identification	Approximate Surface Area, in^2.	Condition	Approximate Dwell Time, hrs.	Approximate Removal Rate, in^2/ min.
Area 1	2.25 2.25	Scored Unscored	6 6	0.520 0.562
Area 2	2.25 2.25	Scored Unscored	22 22	0.843 1.25
Control	2.25	Unscored	N/A	1.58

MCAS New River Demonstration/Validation

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Sealant Removal Times for Sealants Processed with SkyRestore Remover

Test Area Identification	Approximate Surface Area, in^2.	Condition	Approximate Dwell Time, hrs.	Approximate Removal Rate, in^2/min.
Area 1	2.25 2.25	Scored Unscored	2 2	.225 .225
Area 2	2.25 2.25	Scored Unscored	4 4	2.25 .900
Area 3	3.00	Unscored	6	.901

MCAS New River Demonstration/Validation Summary

Dem/Val conducted at MCAS New River, NC (January 26, 27, 2010)

- **Elixair Sky Restore and Solutia SkyKleen 2000 demonstrated on V-22 Osprey components**
  - **Fixed Wing Structure**
  - **Outer Mold Line Elements**
- **Dem/Val conditions affected outcomes**
  - **Unheated hangar resulted in dwell temperatures <40°F, possibly effecting remover efficiency**
  - **Sky Restore exceeded performance of SkyKleen 2000 at more desirable dwell times**

Controlled Temperature Test

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Test Matrix and Sample Specifications

Sample #	Sealant	Sealant Surface Area (in^2)	Sealant Thickness (mils)	Chemical Remover	Remover (grams)	Remover Dwell (hrs)	Temp. (°F)	Coverage ($grams/in^2$)
1	PR1826, Class B	7.1875	66.10	Skykleen	11.34	20	35	1.58
2	PR1826, Class B	7.1875	65.87	Skyrestore	11.26	6	35	1.57
3	PR1826, Class B	7.1875	60.33	Skykleen	11.69	20	50	1.63
4	PR1826, Class B	7.1875	65.23	Skyrestore	11.76	6	50	1.64
5	PR1826, Class B	7.1875	65.60	Skykleen	11.67	20	70	1.62
6	PR1826, Class B	7.1875	64.13	Skyrestore	11.75	6	70	1.63

Controlled Temperature Test

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Removal rates for each test sample according to the subjected temperature

Sample #	Chemical Remover	Remover Dwell (hours)	Temperature (ºF)	Removal Time (min:sec)	Strip Rate (in²/min)
1	Skykleen	20	35	19:53	0.36
2	Skyrestore	6	35	15:41	0.46
3	Skykleen	20	50	5:52	1.23
4	Skyrestore	6	50	5:25	1.33
5	Skykleen	20	70	2:22	3.04
6	Skyrestore	6	70	9:41	0.74

MCCS Cherry Point Demonstration/Validation Summary

Dem/Val conducted at MCCS Cherry Point, NC (June 3, 4, 2010)

- **Elixair Sky Restore and Solutia SkyKleen 2000 demonstrated on AV-* Harrier components**
  - **Fixed Wing Structure**

Results pending at time of briefing submission

TECHNOLOGY TRANSFER

- **Prepare Industry Standard for Removers**
- **Establish NSNs for Removers**
- **Add Removers to Tech Orders**
  - TO 1-1-3 fuel tank repair
  - TO 1-1-8 coating application
  - TO 1-1-691 cleaning/coating application
- **Communication of DEM/VAL Results Across DoD and Industry**
  - Quarterly and final reports
  - Preparation of draft Process Order
  - Presentations at conferences and meetings
  - Life-Cycle Cost Analysis
- **Approach for obtaining DoD and regulatory acceptance**
  - Air Force and Navy Materials Safety Organizations
  - Chemical company chemical registration

PolyGone 310 AG Corrosion Testing

- Concerns with sandwich corrosion testing on PolyGone 300 AG (Phase I)
  - RPM technology responded by modifying COTS formula
  - Submitted new formulation to NAVAIR for additional testing (PAX River)

PolyGone 310 AG Corrosion Testing Results

- Sandwich Corrosion: No corrosion observed on 2024 and 7075 coupons
- Hydrogen Embrittlement: Four test specimens exceeded 75% NFS sustained load for 200 hours
- Effects on Painted Surfaces: Product performed complete coating removal within 30 minutes
- Total Immersion Corrosion: Product met corrosion limits as specified

Test	Specification	Results
Sandwich Corrosion	ASTM F1110	✓
Hydrogen Embrittlement	ASTM F519	✓
Effects on Painted Surfaces	ASTM F502	✗
Total Immersion Corrosion	ASTM F484	✓

PolyGone 310 AG now being considered as compliant coating remover by USAF

UPCOMING ACTIVITIES

- **Complete remaining laboratory testing (UDRI)**
  - Remaining polythioether data
  - Polysulfide data
- **Assess and report on MCCS Cherry Point dem/val for polythioether sealants**
  - Schedule of dem/val reports dictated by remedial action plan
- **Complete Draft Final Report**
  - Submission dependent on schedule for additional dem/val
  - Incorporate Phase I/Phase II activities